Center Innovation Fund: SSC CIF

Development of CFD Approaches for Modeling Advanced Concepts of Nuclear Thermal Propulsion Test Facilities

Completed Technology Project (2014 - 2014)

Project Introduction

The current project is going to investigate, implement and begin validating the Computational Fluid Dynamics (CFD) options available for modeling multi-phase reactive flows in a fully coupled multi-physics framework to use in designing and supporting Nuclear Thermal Propulsion (NTP) Test ground test facilities. NTP is an advanced propulsion alternative to conventional chemical rockets with relatively high thrust and twice the efficiency of the Space Shuttle Main Engine. Ground testing facilities can validate thrust and efficiencies from testing if capturing and treating the nuclear exhaust satisfy current safety, health and environmental regulations. A fully-coupled, multi-physics, CFD analysis approach will be required to design such a NTP ground test facility system. The multi-physics approach will require simultaneous simulations of processes such as transient real-gas hydrogen flow through a supersonic diffuser, Liquid Oxygen/Gaseous Hydrogen (LO2/GH2) combustion at high speeds, and multi-phase condensation and evaporation of water sprays in a reacting flow environment. However, multiphase reactive CFD simulations are not simplistic or straightforward to obtain. In addition, fully coupling these flow simulations with transient thermal analysis of heat exchangers and thermal protection systems significantly increases the complexity. By developing this CFD analysis approach, a better understanding of requirements for NTP ground testing facilities can be better achieved.

The project will be developing a CFD approach that can handle the additional complexities needed in a NTP testing facility when modeling the combustion processes in a transient environment for fluid flows that will extend from low subsonic to supersonic during a typical NTP ground test sequence.   Complex combustion processes will eventually need to be modeled in conjunction with down-stream effluent cooling systems such as water sprays and heat exchangers. The simulation of water spray injection in a transient, time-accurate fashion will require implementation of robust numerical schemes which sufficiently capture the relevant physics of the water spray evaporation in the high-speed combusting flow. In addition, the simulation of heat exchanger cooling systems will require fully coupling these multi-phase combustion simulations with a transient thermal analysis in a multi-physics analysis framework. The successful demonstration of accurately and robustly coupling all these analysis into one simulation environment will be a new achievement for NASA.

Anticipated Benefits

The development of novel CFD approaches for modeling advanced concepts of NTP ground test facilities will benefit NASA's effort to reach Mars by 2033.

The development of novel CFD approaches for modeling advanced concepts of NTP ground test facilities will benefit NASA unfunded and planned mission by enabling space travel beyond capabilities that chemical rocket engines, due to lack of efficiency, restricts. The relatively large fuel consumption of existing

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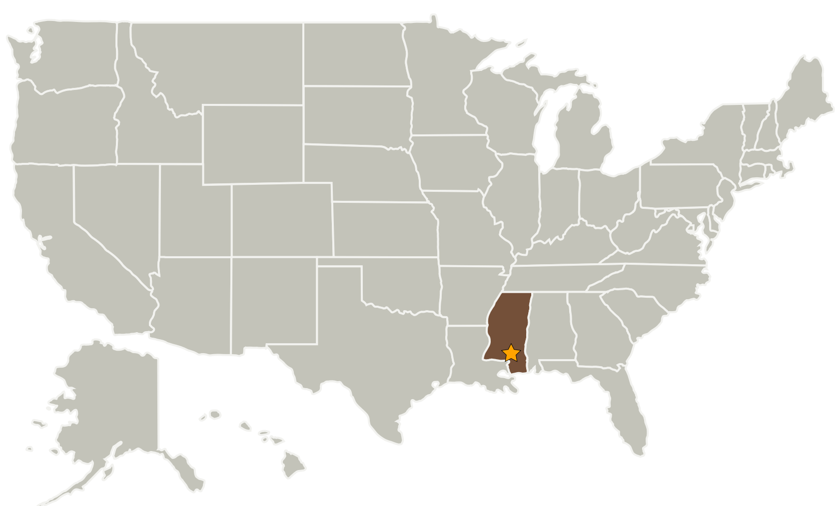
propulsion systems, severely limits the ability to safely execute a manned mission to Mars, and entirely prohibits mankind from exploring beyond the asteroid belt. There are numerous potential alternatives to conventional rockets that could one day take us to the outer solar system and advanced propulsion technologies, like NTP is currently one of the most technically promising approaches. NTP designs are evolving; in order to conduct safe, efficient, and affordable ground test programs, mechanisms for validation must be implemented. CFD plays an important role in analysis, and is required in order to be capable of predicting multiphase reactive flow to support the NTP ground test program.

Benefits to the commercial space industry would be similar to those that would be enabled for NASA. Commercial industry can take the CFD modeling capability and proceed forward to solve more complex problems after validating against the results produced here.

Benefits to other government agencies would be similar to those that would benefit NASA. Novel CFD approaches would enable a better understanding of other related nuclear propulsion technologies (i.e. used by the Army, Navy, DoD, DoE).

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Stennis Space Center (SSC)

Responsible Program:

Center Innovation Fund: SSC CIF

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Ramona E Travis

Project Manager:

Daniel C Allgood

Principal Investigator:

Daniel C Allgood

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Organizations Performing Work	Role	Type	Location
★Stennis Space Center(SSC)	Lead Organization	NASA Center	Stennis Space Center, Mississippi

Primary U.S. Work Locations
Mississippi

Images

Office the Chief Technologist
Log for the Office of Chief Technologist
(https://techport.nasa.gov/image/4038)

Stories

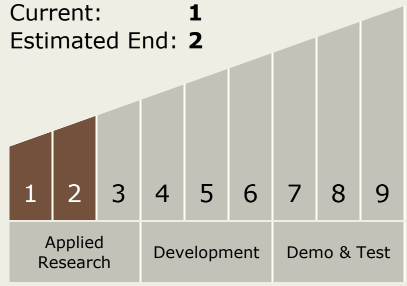
Development of Modeling Approaches for Nuclear Thermal Propulsion Test Facilities
(https://techport.nasa.gov/file/21922)

DEVELOPMENT OF MODELING APPROACHES FOR NUCLEAR THERMAL PROPULSION TEST FACILITIES.
(https://techport.nasa.gov/file/21923)

REVIEW OF NUCLEAR THERMAL PROPULSION GROUND TEST OPTIONS
(https://techport.nasa.gov/file/21941)

Technology Maturity (TRL)

Start: **1**
Current: **1**
Estimated End: **2**



Technology Areas

Primary:

- TX09 Entry, Descent, and Landing
  - └ TX09.4 Vehicle Systems
    - └ TX09.4.5 Modeling and Simulation for EDL